PERSPECTIVE

Primary Thought on Artificial Intelligence (AI) Enhanced Control Engineering Education

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Abstract

This study briefly discusses the primary AI's roles in enhancing control engineering education (CEE), which has the potential to revolutionise the teaching-learning framework by making complex concepts and methodologies more intuitive, interactive, and application-driven. While understanding the potential benefits of these AI tools, such as assisting with problem-solving in education, some of the concerns about their use are summarised. An example is discussed how AI enhances CEE in MATLAB & Simulink. The centre point in the brief paper is that AI should be a tool to enhance teaching-learning, rather than a shortcut to avoid it.

Keywords: generative AI, computational framework, virtual demonstration platform, MATLAB/Simulink, new assessment, AI in education community of practice, ethical issues.

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1 Introduction

Control engineering [1], often referred to as control systems or automation engineering, is an engineering field that focuses on the design and implementation of systems to achieve desired behaviours in dynamic environments. It intersects with multiple engineering fields and is widely taught in university engineering programs worldwide. The subject is characterised with multi-disciplinary knowledge, such as applied engineering, math-based quantitative analysis and design, qualitative understanding of the concepts in feedback, stabilisation, and frequency response, simulation-based demonstrations, for example, using MATLAB/Simulink, and application background, for example, in electrical, mechanical, and process engineering. The conventional teaching-learning style has evolved from practical and experimental to mathematically driven and simulation demonstration. Now, introducing AI tools into the teaching-learning process has been a rapidly expanding tendency [19, 35, 36]. Below is a summary of the historical education in control engineering.

The teaching style of control engineering has evolved significantly throughout history, influenced by technological advancements, mathematical developments, and pedagogical trends. Briefly the history have evolved with 1) Practical and experimental approaches through hands-on experience in mechanical systems such as steam engines, windmills, and water clocks, 2) Graphical

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and analytical methods (Laplace transforms, root locus, and frequency response) by lecture-based teaching, primarily focused on linear time-invariant (LTI) systems, and analogue computers & mechanical demonstrations were adopted to improve practical understanding, 3) Modern control approaches [38] predominantly state space model based approaches are taught and applied, more mathematical tools are introduced in the teaching-learning processes, such as linear algebra and matrix-based approaches, optimisation, and so on. Simulations & Labs have used digital computers and simulation tools (such as MATLAB/Simulink) for students to analyse more complex systems. Microprocessor-Based Learning: The rise of microcontrollers and digital control systems changed the teaching style to include sampling theory, z-transforms, and discrete-time control. Software Tools: The Introduction of MATLAB, Simulink, LabVIEW, and other computational tools revolutionised teaching, allowing interactive simulations. Hands-On Project-Based Learning: Engineering programs emphasized practical applications, including robotics, embedded systems, and real-time control. 4) Contemporary approaches, hybrid learning models, such as using online lectures, virtual labs, and interactive simulations. AI & machine learning in control: teaching incorporates modern techniques such as adaptive control, neural networks, and reinforcement learning. industry-oriented approach, courses have more closely linked to real-world applications with case studies in autonomous vehicles, drones, biomedical control, and Internet of Thing based automation.

Recent advances in AI-integrated engineering education demonstrate transformative potential for CEE pedagogy [21, 23, 31]. The literature reveals three keys to this evolution: First, MATLAB-based simulations significantly enhance conceptual learning [11, 15], where virtual laboratories provide a deeper understanding of complex control systems. Second, project-based approaches using MATLAB/Simulink bridge the gap between academia and industry, enabling students to tackle real-world engineering challenges [10, 25]. Third, cognitive studies [2, 22] reveal that AI-enhanced tools can foster higher-order thinking skills when properly integrated into curricula. Systematic analyses [20, 29] suggest future directions should focus on: Generative AI tools [7], Digital twin technologies [4, 5], Adaptive learning systems. While this technological convergence raises important pedagogical considerations: Ethical implementation [27], Curriculum modernisation needs [6], and optimal balance between AI assistance and core skill development [8]. AI-enhanced MATLAB/Simulink is a powerful but nuanced pedagogical tool that requires careful implementation strategies to maximise educational benefit while mitigating risks [20, 29].

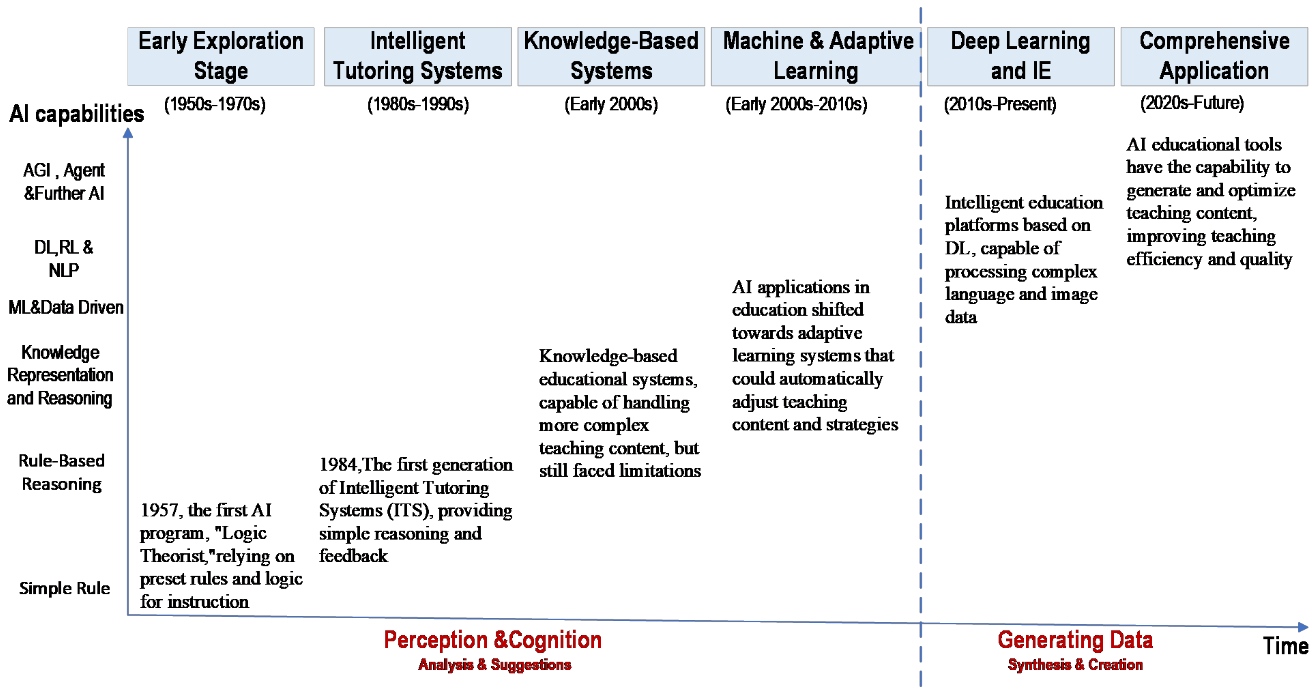

Figure 1. The evolution of the integration of education and AI.

In summary, CEE has evolved from a practical apprenticeship model to a highly mathematical and computer-based discipline, now incorporating AI-driven techniques and industry-relevant projects. The teaching style continues to shift towards interactive, simulation-based, and application-driven learning. Figure 1 illustrates the development of the fusion between education and AI, and the future vision.

2 Primary thought using AI in the subject teaching-learning

This section delves into the fundamental pedagogical principles and methodological approaches for integrating AI into CEE. The integration of education and AI can be traced back to the mid-20th century. As computer technology develops, the field of education has gradually started to explore AI to enhance teaching quality and efficiency [18, 32]. Figure 1 shows the main stages and developments in the integration of education and AI. AI can bridge the gap between theory and real-world application by offering personalised learning, real-time simulations, and automated feedback. This enables teachers and students to grasp some of the challenging subjects in teaching, for example those nonlinear control, adaptive control, and advanced techniques like Sliding Mode Control (SMC) more effectively. The key benefits of AI in CEE include the following:

1. **Interactive simulations & digital twins:** AI-driven virtual labs allow students to test and visualise control algorithms dynamically. For example, real-time tuning of PID controllers in a virtual industrial plant [29].
2. **Automated problem solving & feedback:** AI tutors can provide step-by-step feedback on control system design and stability analysis, for example, identifying errors in MATLAB/Simulink code for control system modelling.
3. **Adaptive learning & personalised curriculum:** AI adjusts content based on the learner's strengths and weaknesses, for example, students struggling with state-space models get extra visual explanations and simpler exercises.
4. **Bridging theory and industry practices:** AI can connect students to real-world datasets, making education more practical, for example, predictive maintenance case studies using AI-based fault detection [30].

As detailed in Figure 2, these applications collectively enhance both the depth and accessibility of CEE. The integration of AI tools not only improves conceptual understanding but also develops crucial skills for modern engineering practice.

3 AI enhanced computational demonstrations by MATLAB & Simulink

This section examines the synergistic integration of AI with MATLAB-based computational methods and simulation techniques in CEE. MATLAB is a high-performance numerical computation and visualisation platform, while Simulink is a graphical tool for simulating and designing models across multiple domains. MATLAB/Simulink is also a teaching tool. Together, they are widely used in engineering education for courses such as control systems, signal processing, and numerical computation. As we delve into the future of engineering education, the synergy between these platforms and emerging technologies like AI becomes increasingly important. This leads us to explore more possibilities for the integration of MATLAB/Simulink and AI.

3.1 Integration of AI and MATLAB

(1) AI and MATLAB/Simulink synergy

MATLAB/Simulink is extensively used for AI-enhanced control engineering education (AIECEE). It offers tools for simulation, analysis, and implementation of control systems [24]. AIECEE typically involves system modelling, real-time testing, optimisation, data acquisition, code generation, and the use of specialised toolboxes for fields such as robotics, power systems, and signal processing. In these areas, AI plays significant roles, such as optimising parameters and models within MATLAB/Simulink, providing higher quality input data through preprocessing, and aiding in making optimal decisions in the design of complex systems.

(2) AI Integration in engineering workflows

MATLAB now offers comprehensive AI capabilities through its DL, Machine Learning (ML) and RL toolboxes. These toolboxes come equipped with interactive apps that allow users to experiment with different algorithms and models without extensive coding. Additionally, MATLAB provides a library of pre-trained models that can be easily adapted and fine-tuned for specific applications. This is particularly useful for tasks such as image recognition, NL processing, and time-series analysis. Beyond those

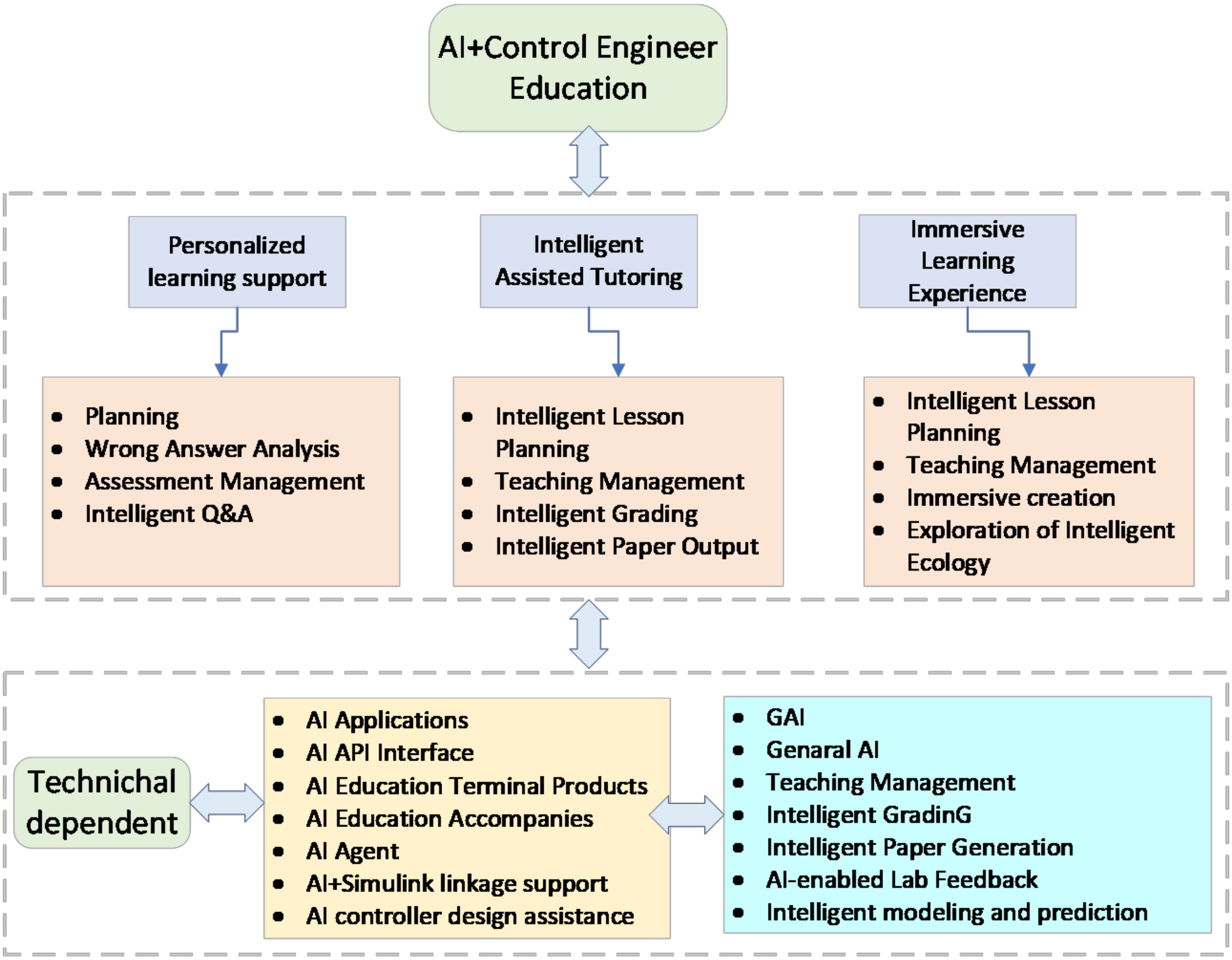

Figure 2. The primary thought using AI in control engineering.

areas, MATLAB's integration with Simulink enables AI models to be directly deployed in embedded systems or digital twins and helps make experiments more closely match real-world conditions [37]. AI itself also becomes a design partner to optimise controllers [28]: students can leverage genetic algorithms or RL to automatically tune controller gains, achieving optimal stability and performance without manual iteration.

(3)Development with MATLAB/Simulink
Vice versa, conversely, MATLAB/Simulink supports AI development through robust model validation tools, real-time Hardware Interaction, and an integrated environment for AI education and research. For example, the Intelligent Control Systems course [34] demonstrates the power of this integration by incorporating AI algorithms into control system design. This approach not only enhances the overall workflow but also enables students to explore advanced optimisation techniques and develop cutting-edge solutions for real-world problems.

(4)Potential highlighted areas
Looking ahead, integrating teaching AI with MATLAB and Simulink promises to be a key highlight (Tables 1 and 2). This integration includes strategies in teaching AI + X with MATLAB and Simulink, tools for educational purposes, such as MATLAB Apps, MATLAB Online. Furthermore, MATLAB and Simulink's cost-effective hardware connectivity allows students to connect their AI models to real-world devices, such as sensors and microcontrollers. Moreover, the future landscape includes interoperability with Python and low-cost hardware solutions, expanding the scope of possibilities within educational environments. Knowledge transfer stands to be revolutionized by self-paced online training modules, catering to diverse learning styles and needs. Lastly, implementing automated assessment tools like MATLAB Grader

Table 1. Examples of AI in Control Engineering using MATLAB and Simulink.

Category	Description	Example
AI-driven control system design	Reinforcement Learning Toolbox: Helps in designing controllers that learn optimal strategies over time.	Training an AI-based adaptive cruise control system using reinforcement learning. See Table 2.
Automated parameter tuning & optimization	Optimization Toolbox & (DL) Toolbox: AI can fine-tune controller gains (PID, LQR, etc.) for optimal performance.	AI-based tuning of PID controllers for DC motor speed control.
Predictive control & model identification	System Identification Toolbox: Uses AI to create mathematical models from experimental data. Model Predictive Control (MPC) Toolbox: AI can optimize future control actions dynamically.	AI-assisted process control in chemical plants for energy efficiency.
AI for fault detection & predictive maintenance	Machine Learning Toolbox: Detects anomalies and predicts system failures before they occur.	AI detecting sensor faults in an aircraft flight control system.
AI-assisted simulations & virtual labs	Simulink with AI Integration: Allows real-time simulation of complex control scenarios.	Simulating an autonomous vehicle control system with AI-based decision-making.

Table 2. AI Technologies in CEE.

AI Development	Contribution to CEE	Tools/Applications
Deep Learning (DNN, LSTM, CNN)	Data-driven modelling of nonlinear systems, system ID, fault detection	MATLAB DL Toolbox, Simulink DL blocks
RL	Learning optimal control policies, adaptive control, path planning	RL Toolbox, Simulink + OpenAI Gym, Simscape
NL Processing [17]	Auto-generate explanations, MATLAB code from NL, tutoring	ChatGPT, MATLAB GPT APIs, NL→Simulink translation
Explainable AI (XAI)	Interpret AI-based control decisions for student understanding	SHAP, LIME, MATLAB XAI Toolbox, Simulink Interpretability layer
GAN+ GAI [7]	Scalable, personalized, AI-tuned virtual experiments	MATLAB AI Builder, NVIDIA Isaac Sim, Simulink, MIT iLabs
Neural ODE / Physics-Informed Neural Networks	Teach hybrid modelling: physics + data-driven learning	DL Toolbox +Symbolic Math Toolbox+ PyTorch, Neural ODE blocks in Simulink
AutoML / AI-assisted Code Generation	Auto-tune controllers, generate embedded code, lower entry barrier	MATLAB AutoML, Simulink Coder, RL Designer
AI-based Assessment & Feedback (NLP model, GPT model, AI Tutor) [14]	Auto-grade control design tasks, generate personalized feedback	MATLAB Grader + AI plugins, AI-driven diagnostics, AI Fairness 360, PeopleGPT, Knewton, GitHub Copilot
AI + Low-cost Hardware Integration	Deploy AI controllers to Arduino, Raspberry Pi for hands-on learning	MATLAB Support Packages, Simulink External Mode
Multimodal AI (Vision + Voice+Text + Signals)	Teach vision-based control (e.g., drone navigation) using AI	MATLAB Computer Vision Toolbox + RL Toolbox

ensures efficient evaluation processes, fostering continuous improvement and personalised feedback mechanisms for learners. Some of the examples are listed in Table 1, showcasing the practical applications and implementations of these innovative engineering education strategies involving teaching AI with MATLAB and Simulink.

Several recent AI developments—especially in DL, NL processing, and RL—are starting to reshape CEE. Here's a summary in Table 2 for the most impactful AI developments in CEE.

Table 3. Challenges and Solutions in Integrating AI into CEE.

Challenge	Specific Issues	Possible Solutions
Ensuring Originality & Academic Integrity	1. AI can generate detailed answers to theoretical and practical questions, making plagiarism detection 2. AI-generated content might bypass traditional plagiarism detection tools (e.g., Turnitin).	1.Design AI-resistant assessments (e.g., ask students to interpret, critique, or modify AI-generated solutions). 2.Use oral defense or interviews to verify individual understanding. 3.Implement code similarity checks in MATLAB/Simulink projects.
Assessing True Understanding vs AI-assisted Work	1. AI provides accurate results, yet it doesn't guarantee comprehension of the underlying control design concepts. 2. Detection tools may struggle to fully distinguish between AI-generated content and human writing.	1. Require step-by-step problem-solving with reasoning and manual tuning in MATLAB, not just AI-generated solutions. 2 Conduct practical or viva-based assessments where students demonstrate and explain their work.
Balancing AI as a Learning Aid vs. a Shortcut	1. AI can enhance learning but also reduce problem-solving effort if students copy answers blindly. 2. Relying too much on AI might weaken critical thinking and mathematical modelling skills.	1. Design coursework where AI is an assistant, not a solver (e.g., AI can suggest a solution, but students must critique/improve it). 2. Assign hands-on implementation tasks (e.g., students must physically build or simulate a control system in MATLAB/Simulink).
Keeping Exams Fair Across Different AI Access Levels	1. Some students may have better AI tools, giving them an unfair advantage. 2. Variability in AI-generated answers can lead to grading inconsistencies. 3. Diminishes exam performance when independent skills are untested.	1.Specify which AI tools are allowed and provide university-approved versions. 2. Use closed-book, controlled environments (e.g., MATLAB On-Campus or restricted exam-mode tools). 3.Design exams where AI cannot directly solve the problems, requiring unique critical thinking. like explanatory assignments, handwritten derivations, and oral explanations in exam (e.g., Explain why a human engineer might choose different parameters).
Evaluating Advanced Thinking & Creativity	1. AI can solve routine numerical problems, reducing the need for manual calculations. 2. Creativity in control system design may be overshadowed by AI-generated solutions.	1. Shift towards project-based learning where students design, simulate, and defend unique control systems. 2. Ask students to compare multiple control strategies and justify their selections beyond AI's recommendations (e.g., explain why this works requires human insight and weigh non-quantitative factors).

3.2 Pedagogical value of the AI-MATLAB/Simulink framework

Integrating AI into MATLAB/Simulink enhances control engineering education by making it more personalised, interactive, and adaptive. Students can now design and analyse control systems with greater ease, thanks to features like natural language (NL) coding, which lets them describe models in plain English rather than writing complex scripts. By features such as: 1) NL to code conversion, helping students implement models and controllers without deep prior coding knowledge, 2) real-time feedback and debugging, identifying errors in MATLAB scripts or Simulink diagrams and suggesting improvements, 3) intelligent tutoring, guiding students through complex topics like PID tuning, state-space modelling, and system stability, 4) building up adaptive simulation scenarios, generating dynamic tasks based on student performance.

The AI also acts as a real-time mentor, like 1) providing instant feedback, 2) allowing live interaction with AI assistants embedded within the MATLAB/Simulink environment or via an educational platform, and 3) simulating real-world control scenarios, including disturbances and nonlinearities, helping students visualise system behaviour and controller performance dynamically.

Beyond individual learning, For the scalability in academic settings, the framework should be 1) scalable across institutions due to cloud-based AI tools and APIs that integrate with MATLAB online and Simulink online, 2) having auto-assessment capabilities [14], which reduce instructor workload by automatically grading and analysing student submissions, 3) enabling modular design, allowing instructors to tailor AI features to specific courses or learning outcomes, 4) supporting for diverse student backgrounds, enabling self-paced learning and bridging gaps in coding or theoretical knowledge.

Table 4. Problems to be considered.

Challenges	Considerations
Cost [26, 27]	Implementation costs might limit accessibility like: 1. Energy exhaustion and Carbon Emissions 2. Advanced technological infrastructure required 3. Constant curriculum updates 4. Continuous teacher training 5. Restructuring students' basic training in mathematics, statistics, and computing
AI bias interpretability [13]	1. AI systems may produce discriminatory results due to bias in training data 2. Deviation from educational objectives 3.Make complex decisions harder to explain.
Ethical issues [6]	1. Roles changes of teachers, 2.Deviation from student holistic development, 3. Academic misconduct due to technological abuse 4. Security infringement induced by data leakage.
AI Deepfakes [33]	1.Triggered by AI are the most concerning issue for respondents 2. The content generated by AI may contain errors or inaccurate information 3. The problem of technological illusion
Over-reliance on AI	1. May reduce interpersonal interaction. 2. Overlooking Real-World Constraints. 3. Magnifies human intelligence, but can also magnify ignorance

In brief, AI boosts MATLAB/Simulink learning by acting as a tutor, debugger, and assistant, it also enabling NL processing, personalised feedback, and adaptive simulations to be more intuitive. These capabilities simplify complex concepts in control engineering and enhance the accessibility and engagement of tools like MATLAB/Simulink.

4 Challenges and possible solutions

4.1 Assessment design challenges with AI

AI tools can introduce innovative teaching and learning approaches. It can help educators with lesson planning, enhancing classroom interaction, automating administrative tasks, and other responsibilities. Research [12] suggests that generative AI tools such as ChatGPT are increasingly capable of producing text and even performing mathematical calculations at a level that allows them to pass some exams [7]. This development poses significant risks to the validity of traditional assessment methods. Some people worry that relying too much on AI might weaken the relationships between educators and learners, or even lead to a disconnect between them. Concerns also include the risk that AI doing student work might damage their writing and critical thinking skills [32].

Many governments have set up relevant policies by their country's concerns and the guidance for their operation. For example, A report on generative AI in education was released by the UK Department for Education in November 2023 [9]. The government pledged up to £2 million for AI-powered resources for teachers in England. Stakeholders emphasise the need for evidence of the effectiveness of AI, training and guidance for educators, and clearer legal frameworks for data usage. They also indicate that there is a need to tackle 'digital divides' from access, usage, quality, opportunity, etc., to prevent artificial intelligence from exacerbating inequality. As AI tools like MATLAB, Simulink, and ChatGPT [3, 18] become widely available, designing fair and rigorous examinations and coursework in control engineering becomes challenging. Here are the key issues briefly summarised list as Table 3 [9].

4.2 Additional AI-related challenges in education

The application of AI in education is not inevitable. AI may fundamentally change the behaviour of teachers and students and the organisation and governance of education [27], except for Potential environmental problems caused by energy exhaustion and Carbon Emissions when training an AI model. There are also problems and more considerations about the application of AI in control engineering that can be found in Table 4.

AI has partially addressed key challenges in teaching nonlinear systems by improving simulation, visualisation, and support for individualised learning. However, it does not yet fully replace the need for human instruction in building deep theoretical insight and critical thinking, especially for complex, nonlinear control topics. Instead, AI serves best as a complementary tool that enhances engagement, accessibility, and experimentation in traditionally difficult areas like nonlinear systems. The progression integrating AI with nonlinear dynamic control is not completely satisfactory so far, still in improving.

In conclusion, the integration of AI into education, particularly in the realm of control engineering, presents a complex interplay of opportunities and challenges. Although AI has the potential to enhance educational practices, improve learning experiences, and simplify administrative tasks, we need to carefully consider and plan it. Table 4 shows some different challenges from Table 3, ranging from cost and environmental effects. In the future, numerous additional technical challenges still exist. For instance, the effective integration of AI in education can be blocked by software and hardware. Similarly, to keep AI models and data safe in education, where privacy is essential. Advanced encryption and stringent access controls will be vital. Moreover, as AI algorithms keep evolving, we need an educational system that can adapt quickly to stay current with technological changes. Tackling these and other new technical challenges will be key to using AI in CEE successfully. We propose to build an educational world that's more open to everyone and encourages customers to implement new ideas with human insight more easily, but not as a replacement.

4.3 Ethical, Educational and Technical Difficulties

Using AI in control engineering education requires careful consideration of ethical principles, pedagogical goals, and technical feasibility [35, 36]. The key is augmenting, not replacing, the learning experience—ensuring students gain both practical skills and conceptual understanding while maintaining fairness and academic integrity. Learnt from ChatGPT, and revised with the author's insight, please find the following response.

1. Ethical difficulties

   (a) Bias and fairness: AI systems may inherit or amplify biases from training data, leading to unfair educational outcomes. Students from underrepresented groups may face disadvantages if the AI lacks diverse training data or the questions cannot be described properly in relation to the answer options.

   (b) Privacy concerns: AI systems often rely on collecting and analysing student data, raising concerns about consent, transparency, data security, unauthorised access and so on.

   (c) Academic integrity: Generative AI tools can make it easier for students to cheat (e.g., by generating code or solutions without understanding or proper explanation to the reasoning and solution processes). Differentiating between genuine understanding and AI-assisted work becomes harder, even spending extra effort/time.

   (d) Autonomy and over-reliance: Students may rely too heavily on AI tutors or tools, reducing the development of critical thinking and problem-solving skills. This could impact the conventional education system dramatically.

2. Educational difficulties

   (a) Pedagogical misalignment: Many AI tools are not tailored for the specific needs of control engineering, a field that blends theory with practical applications. Misalignment between AI recommendations and course learning objectives may lead to confusion. Accordingly, teachers require more knowledge to explain and balance the expected from ad hoc applications and answered from Ais.

   (b) Loss of intuition: AI can provide solutions without explaining the reasoning behind them, which can lead to students achieving results without developing the intuition expected to understand system dynamics, control strategies, and whole system configuration, and so on, naturally cultivated in conventional education systems.

(c) Instructor adaptation: Instructors may lack the training or resources to effectively integrate AI into their teaching. Possibly even there is certain resistance to adopting new technologies due to unfamiliarity or mistrust. In essence, lecturers/instructors need more knowledge and training before taking up such supervisory tasks [16].

3. Technical difficulties

(a) Model transparency and explainability: Many AI models (e.g., DL) are black boxes. Obviously, it is very difficult to understand or debug AI-generated solutions, which is problematic in a field that emphasises model behaviour and response.

(b) Data requirements: AI systems require significant amounts of high-quality, labelled data, which might be unavailable or expensive to generate in control engineering.

(c) Integration with existing tools: Control engineering relies on specialised software like MATLAB/Simulink, which may not easily integrate with AI platforms. Ensuring such compatibility and meaningful outputs can be technically challenging.

(d) Robustness and reliability: AI systems might not perform well on out-of-distribution examples or complex nonlinear systems often encountered in advanced control topics and application. Unreliable suggestions can mislead students or result in failed lab experiments, and correction back will take tremendous effort/time.

5 Conclusion

AI presents transformative opportunities for CEE, allowing for more adaptive, efficient, and personalised learning experiences. Integrating AI driven tools into the curriculum can enhance the implementation of complex modern control systems while promoting deeper engagement and understanding. This paper highlights the primary considerations and potential frameworks for integrating AI into CEE. It emphasises the necessity for interdisciplinary collaboration, updated curricular structures, and adhering to ethical awareness. With the continuous evolution of AI, its deep integration into education will be critical to the next generation of engineers for intelligent, data-driven environments. Once again, AI should become an important tool for enhancing CEE, rather than avoiding it or seeing it as a shortcut to laziness.

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Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

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